Ultrasound-guided placement of peripherally inserted intravenous catheters increase catheter dwell time in children

James Thomas Cottrell¹, Todd Chang², Jennifer Baird¹, Joanna Barreras¹ and Marsha A Elkhunovich²

Abstract

Objective: To compare the dwell times of ultrasound-guided and non-ultrasound-guided short peripheral intravenous catheters in hospitalized children.

Methods: This was a retrospective analysis of data from 256 ultrasound-guided and 287 traditional peripheral intravenous catheters placed in hospitalized children between 1 September 2016 and 31 October 2016 at a free-standing children’s hospital with a 10-member vascular access team. A two-sample independent t test and Kaplan–Meier estimator were used to assess differences in dwell times between the ultrasound-guided peripheral intravenous catheters and non-ultrasound-guided peripheral intravenous catheters. Child age, peripheral intravenous catheter location, and subjective difficulty of placement were also analyzed.

Results: There was a significant difference in mean hours of dwell time for ultrasound-guided versus non-ultrasound-guided peripheral intravenous catheters (96.06 vs 59.39, \( p < 0.001 \)). Mean increase in dwell time was 36.68 h (95% CI: [24.14–49.22]). Median dwell times (50% probability of survival) for ultrasound-guided and non-ultrasound-guided peripheral intravenous catheters were 118 h (95% CI: [95–137]) and 71 h (95% CI: [61–79]), respectively. None of the additional covariates were significant predictors of dwell time.

Conclusion: Peripheral intravenous catheters placed using ultrasound-guided methods had a significantly longer dwell time than those placed using non-ultrasound-guided methods in a cohort of hospitalized pediatric patients. This is in line with the findings in the adult literature and may suggest a need to increase the use of ultrasound-guided method for peripheral intravenous catheter placement in pediatric practice.

Keywords

Ultrasound, intravenous catheter, point-of-care ultrasound, dwell time

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Introduction

Peripheral venous cannulation is one of the most common and important nursing practices performed in children in the hospital setting. Hospitalized children often have difficult peripheral venous access (PVA) and therefore commonly require multiple attempts to gain venous access.¹ This procedure is often painful to the child and upsetting to the family. Reducing the number of peripheral venous cannulations could decrease psychological and physiologic

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Ultrasound-guided (USG) peripheral intravenous access continues to gain wider acceptance in the medical community due to its high success rate in patients with difficult venous access. While adjunct technologies to improve vein visualization have been shown to improve peripheral intravenous catheter (PIV) insertion success rates, it is also important to know whether the insertion technique contributes to the longevity of the PIV and ultimately, the dwell time, particularly for patients experiencing a prolonged hospitalization. Factors that influence dwell time in pediatric PIVs have been studied, but less so using USG as an insertion technique. The use of ultrasound in this population may increase the dwell time of the PIV insertion, thus reducing the total number of PVA insertions needed for the child during a hospital admission.

The objective of this study was to determine differences in dwell time for PVA catheters in hospitalized pediatric patients inserted by experienced nurses using USG compared to more traditional non-ultrasound-guided (NUSG) PVA techniques.

**Methods**

**Setting and population**

This is a retrospective study that collected data from 1 September 2016 through 31 October 2016, at an urban 350-bed tertiary, free-standing pediatric hospital with a specialized 10-member vascular access team (VAT). Inclusion criteria for the study sample included all children between 0 and 18 years old who were admitted at the children’s hospital and for whom the VAT was consulted for PVA. All patients who had PVA performed by non-VAT personnel were excluded. Patients who had multiple visits with separate VAT consultations were counted separately. The study was approved by the Institutional Review Board (CHLA-16-00472) at our institution. No consent was obtained as data that were already collected for other purposes were only used for this study.

Members of the VAT were experienced registered nurses who received intensive training on all PVA techniques. Team member PVA experience ranged from 8 to 25 years. The VAT members were on call throughout the hospital for patient PVA needs as requested by patient care staff 24 h a day, 7 days a week. Following a call from a care team, the on-call VAT member assessed the patient and selected the location and technique for PVA, including the use of any adjunct technologies. Techniques for PVA were based on personal preference of each team member, and no external influence was given in any way to the technique chosen. Besides visualization and palpation, the VAT members also had access to three AccuVein® (Avant Medical, Cold Spring Harbor, NY, USA) non-contact infrared vein illuminators, Sonosite® S-ICU and Sonosite® S-Cath (Fujifilm, Bothell, WA, USA) ultrasounds, and one Astoria® transilluminator (Stihler Electronics, Stuttgart, Germany).

The catheters used for peripheral access were 20-, 22-, and 24-gauge catheters BD Nexiva® which ranged in length from 0.75 in. to 1 in.

**Variables and data collection**

All VAT attempts were logged as standard of care using data collection tool (Supplemental Online Appendix A) to record all qualifying PVAs performed by the VAT members. In addition, researchers reviewed the electronic health records for all patient encounters included in this study to determine PIV removal or failure throughout the hospital stay.

The primary outcome variable was dwell time, expressed in hours. Dwell time was defined as the length of time the PIV catheter remained in the patient in working condition. This was determined by calculating the time difference between the insertion date/time and the removal date/time.

The primary independent variable was PVA technique, divided into a binary possibility: USG or all other NUSG or traditional techniques. Traditional techniques include visualization and palpation and transillumination using the AccuVein or Astoria transilluminator. For this analysis, we combined these three techniques together as the comparison group against USG.

PVA-level variables were also collected including body location of the PIV, the size (gauge) of the PIV catheter, and perceived difficulty of the PVA insertion. Perceived difficulty was documented as a binary yes versus no as a subjective opinion of the VAT member.

**Data analyses**

For the primary analysis, the two sample independent t test was used to evaluate whether there is a statistically significant difference in the length of dwell time (in hours) between ultrasound-guided peripheral intravenous catheter (USGPIV) and traditional techniques.

For the secondary analysis, the Kaplan–Meier estimator was used to estimate the survival function (dwell time) for each of the two techniques. In the survival curve, an event is defined as a removal of the successful PIV insertion. A log-rank test was run to determine whether there were differences in the overall survival distribution for the two PVA techniques. An analysis of variance (ANOVA) was used to determine whether age as a covariate had an effect on dwell time for the two insertion groups. The significance level was set at $p < 0.05$ for all analyses and conducted using two statistical packages, SAS 9.4 and R 3.3.1.
Results

Over the course of the 2-month study period, 256 USGPIV placements and 287 NUSG traditional PIV placements were done. The mean patient age was 5.8 years (95% CI: [0–11.7]).

USGPIVs were placed very frequently in the forearm and antecubital region while traditionally placed PIVs had more variable locations (p < 0.001; Table 1). Size of PIV for both USGPIV and NUSG traditional PIV placement varied in this study with USGPIVs being larger than NUSG traditionally placed PIVs (p < 0.001). Fewer USGPIV PVAs were perceived as “difficult” by a VAT member compared to those PVAs placed using NUSG traditional technique (p = 0.004; Table 1).

There was a statistically significant difference in hours of dwell time for USGPIV (M = 96.06, SD = 91.55) and NUSG traditional PIV (M = 59.39, SD = 47.69) method. The mean difference in dwell time was 36.68 h longer for USGPIV versus NUSG traditional techniques (95% CI: [24.14–49.22], p < 0.0001). Age as a covariate did not affect dwell times for PIVs inserted using USGPIV versus NUSG traditional techniques (ANOVA p = 0.26 and partial $\eta^2 = 0.002$).

Discussion

This study adds to a growing body of literature that demonstrates the superiority of USGPIV when compared to NUSG traditionally placed PIVs in the hospital setting. We were able to demonstrate that USGPIV placement had a significantly longer dwell time in the pediatric population. We believe this has important implications for pediatric nursing practice and can be used to begin to evaluate current PIV placement practice in the pediatric setting.

Our data suggest that the use of USGPIV leads to different behaviors among the VAT members. The selection of the body part was substantially different for VAT members with USGPIV, who preferred and succeeded primarily in the forearms and antecubital areas. Fields et al. found that among USGPIV in adult patients, longevity of dwell time was highest in the antecubital fossa or the forearm compared to the upper arm. It is unknown whether Fields’ findings were part of the decision-making process for the VAT members in choosing the body location. Furthermore, there were less “difficult” insertions and thicker gauges with USGPIV, suggesting higher levels of confidence and success with direct USGPIV visualization. This is in line with Blaivas et al.’s study on emergency department nurses who perceived USGPIV to reduce the difficulty in “difficult access patients.”

In the Kaplan–Meier curve, a log-rank test showed that the survival distributions for the two methods were also statistically significantly different ($\chi^2(1) = 44.66$, p < 0.001; Figure 1). Median dwell times (50% probability of survival) for USGPIV and traditional PIV were 118 h (95% CI: [95–137]) and 71 h (95% CI: [61–79]), respectively.

Table 1. Summary statistic of categorical variables.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Traditional</th>
<th>USGPIV</th>
<th>All</th>
</tr>
</thead>
<tbody>
<tr>
<td>PIV location</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L saphenous</td>
<td>15 (5.23)</td>
<td>3 (1.17)</td>
<td>18 (3.31)</td>
</tr>
<tr>
<td>Left upper arm</td>
<td>2 (0.70)</td>
<td>2 (0.78)</td>
<td>4 (0.74)</td>
</tr>
<tr>
<td>Left antecubical</td>
<td>3 (1.05)</td>
<td>12 (4.69)</td>
<td>15 (2.76)</td>
</tr>
<tr>
<td>Left forearm</td>
<td>45 (15.68)</td>
<td>122 (47.66)</td>
<td>167 (30.76)</td>
</tr>
<tr>
<td>Left foot</td>
<td>18 (6.27)</td>
<td>1 (0.39)</td>
<td>19 (3.50)</td>
</tr>
<tr>
<td>Left hand</td>
<td>56 (19.51)</td>
<td>0 (0.00)</td>
<td>56 (10.31)</td>
</tr>
<tr>
<td>Left wrist</td>
<td>10 (3.48)</td>
<td>1 (0.39)</td>
<td>11 (2.03)</td>
</tr>
<tr>
<td>L saphenous</td>
<td>13 (4.53)</td>
<td>1 (0.39)</td>
<td>14 (2.58)</td>
</tr>
<tr>
<td>Right upper arm</td>
<td>2 (0.70)</td>
<td>4 (1.56)</td>
<td>6 (1.10)</td>
</tr>
<tr>
<td>Right foot</td>
<td>19 (6.62)</td>
<td>0 (0.00)</td>
<td>19 (3.50)</td>
</tr>
<tr>
<td>Right antecubical</td>
<td>6 (2.09)</td>
<td>11 (4.30)</td>
<td>17 (3.13)</td>
</tr>
<tr>
<td>Right forearm</td>
<td>40 (13.94)</td>
<td>99 (38.67)</td>
<td>139 (25.60)</td>
</tr>
<tr>
<td>Right hand</td>
<td>48 (16.72)</td>
<td>0 (0.00)</td>
<td>48 (8.84)</td>
</tr>
<tr>
<td>Right wrist</td>
<td>9 (3.14)</td>
<td>0 (0.00)</td>
<td>9 (1.66)</td>
</tr>
<tr>
<td>Scalp</td>
<td>1 (0.36)</td>
<td>0 (0.00)</td>
<td>1 (0.18)</td>
</tr>
<tr>
<td>PIV location (aggregated)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Forearm + antecubal</td>
<td>94 (32.75)</td>
<td>244 (95.31)</td>
<td></td>
</tr>
<tr>
<td>All other areas</td>
<td>193 (67.25)</td>
<td>12 (4.69)</td>
<td></td>
</tr>
<tr>
<td>PIV size</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20 Gauge</td>
<td>2 (0.70)</td>
<td>43 (16.80)</td>
<td>45 (8.29)</td>
</tr>
<tr>
<td>22 Gauge</td>
<td>107 (37.28)</td>
<td>190 (74.22)</td>
<td>297 (54.70)</td>
</tr>
<tr>
<td>24 Gauge</td>
<td>178 (62.02)</td>
<td>23 (8.98)</td>
<td>201 (37.02)</td>
</tr>
<tr>
<td>Difficult</td>
<td>N 71 (24.74)</td>
<td>92 (35.94)</td>
<td>163 (30.02)</td>
</tr>
<tr>
<td></td>
<td>Y 216 (75.26)</td>
<td>164 (64.06)</td>
<td>380 (69.98)</td>
</tr>
</tbody>
</table>

Figure 1. Plots of Kaplan–Meier estimates of survival of a group of patients using Traditional PIV (Trad) and USGPIV (US) methods.
The success of a PIV is measured in two ways in the literature: insertion success and dwell time longevity. USGPIV is known to improve insertion success rates leading to higher patient (and family) satisfaction. Even nuances in USGPIV technique—such as the choice of visualization axis (short vs long axes)—has an effect in insertion success. However, USGPIV is not the only visualization technique—prior to the introduction of the USGPIV at our hospital, near-infrared visualization using the Accuvein was found to improve insertion success rates compared to traditional techniques in a subset of pediatric patients, children with special health care needs. These children have particularly difficult access needs given their frequent hospitalizations and morphological differences.

Our data show that USGPIV may be a positive factor in dwell time longevity for PIV in children, though there are few studies within this population specifically looking at USGPIV and dwell time. Among adult patients, other contributory factors include anatomical location and vessel depth. Phlebitis, which hastens PIV removals, were also adversely affected by anatomical location in the hand, with antecubital fossa and forearm being more favorable. Other factors adversely affecting dwell time in the literature during insertion include staff skill.

This study does have some limitations, clustered in several domains. One limitation domain is clinical factors outside of the VAT control: the types of medications and fluids used or chronicity of the patient’s illness. For example, high-dextrose concentration fluids like D10 which are common among hospitalized infants, are known to independently shorten dwell time. An additional domain is the post-PIV care, including excess movement—particularly in children—and methods for securing. Each of these may have impacted the choice of placement strategy or the PIV dwell time.

Another comes from the data source. This study was retrospective and single center, and the data may therefore not be representative of other pediatric acute care facilities.

Because of the retrospective nature, we were dependent on the accuracy and completeness of the medical records. Finally, dwell time when visualized using the survival curve does not differentiate between PIVs which would have failed due to extravasation, dislodgment, or phlebitis versus PIVs removed at the end of the inpatient visit. Furthermore, the insertion site of the USG PIVs and NUSG traditional PIVs were different with more USG PIVs in the forearm/antecubital region, which may be a cofounder.

The findings from this study suggest that the use of USGPIV in hospitalized children may decrease the need for multiple PIVs during hospital stays by extending dwell time beyond that of NUSG traditional PVA insertion techniques. Continued study and implementation of USGPIVs in this population may influence future practice by increasing USGPIV placement opportunities. Further study can delineate the exact effect of USGPIV on improving pediatric PIV dwell time independent of additional factors identified in our study and in the literature.

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References

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